The Application of Embedded System and LabVIEW in Flexible Copper Clad Laminates Detecting System*

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(Abstract) With regard to the disadvantages of high failure rate, instability of performance and low detection precision and visualization ability of Flexible Copper Clad Laminates performance detecting equipments, this paper designs and develops a kind of embedded intelligent detecting system taking the LabVIEW software as the monitoring software. This system makes full use of the advantages of easy to upgrade, open and flexible of the virtual instrument of LabVIEW software, and the functionality of dealing with multiple tasks in real time of embedded system, to achieve automatic control by the GPIB bus communicating with PC. The practical experiments show that the designed detecting system can make a significantly improvement in resolution, speed of response and stability, which has a higher application value in engineering.

Keywords: Flexible Copper Clad Laminates; Embedded System; GPIB Interface; LabVIEW

1. INTRODUCTION

With the increasing development of science and technology, electronic products become more and more miniaturized, lightweight and thinner in recent years, which prompts the Flexible Copper Clad Laminates (FCCL) plays an increasingly important role in the manufacturing and printing of electronic components. On one hand, Flexible Copper Clad Laminates retain the good characteristics of a rigid plate such as dielectric properties, bond strength, and dimensional stability and so on. On the other hand, it has the good deflection characteristics, namely: (1) it can be easily bent which can be applicable for dynamic linking; (2) it is also able to be wired in three-dimensional spaces to narrow the line space. Therefore, the status of FCCL in the electronic information industry can not be ignored, which prompts a higher demand of performance detecting in FCCL.

However, the current FCCL performance testing equipments, which are being widely used in the production, are usually taking the Windows95 as the host computer operating interface system and the 51 series microcontroller as the main controller.

This type of testing equipments has the poor stability, low accuracy and low visibility during the debugging process. In view of this, the paper designs a highly intelligent control system under a new framework, and the main innovations focus on the PC monitoring system and the master as following:

(1) The detection device control systems currently in used are often taking the 51-series single-chip as the CPU. Since this kind of CPU is limited by their own resources and performance, then it is difficult for them to carry out the real-time multi-task processing, which leads to the poor testing performance stability

and synchronization, low accuracy and the high failure rate. The master designed in this paper takes full advantages of the ARM chip, which has the rich system resources and high-speed data processing capabilities, and is supported by the IAR PowerPac real-time operating system (RTOS) to achieve multi-task coordinate handling. Thus, it improves the speed of calculation and the accuracy of data collection and processing, and enhances the resolution of the detection system.

(2) The traditional PC monitoring systems designed based on the Windows95 platform have more vulnerability, and are difficult to upgrade, also the corresponding update cost is very high. In order to achieve the transition of the FCCL performance testing and control system software to the environments of Windows XP / Windows 7, this paper uses the virtual instrument of LabVIEW produced by NI Company as the development platform software. It takes full use of the advantages of easy and intuitive graphical programming, a large number of source-level device drivers, a wide variety of analysis and presentation of the LabVIEW, combining with the advantages of the real-time multi-tasks processing of the embedded systems, to develop a real-time detection system with efficient data processing capabilities. Since the detection system uses the LabVIEW software to write the PC monitoring procedures and testing interface program, so as to achieve the basic computation of the detection device and the creation of the management platform, then it has the high visualization and good compatibility, and is open, flexible and easy to upgrade.

2. DETECTION PRINCIPLE AND DESIGNE

The main test items of the FCCL include the peel strength, tensile strength (elongation) of the material and chemical resistance.

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*Special description of the title. (dispensable)

The detection instrument uses the principle of constant velocity tensile test to comprehensive estimate the extent of firm between the interlining and the fabric adhesive by computing the average value and the dispersion coefficient of all peaks on the force curve during the stripping process of the interlining and fabric.

The achievement of the stable pressure and the constant speed are two key technologies in designing the detecting system. In order to achieve stable pressure, this detecting system uses a high-sensitivity pressure sensor to precisely conditioning zoom the detected pull signal by pre-designed pressure signal conditioning circuit, and then passes these enlarged signals to the ARM processor-based PowerPac RTOS for high-speed processing. Afterwards, these processed data are analyzed by the PC monitoring LabVIEW software.

As a result, it not only guarantees the real-time processing of the data and tasks, but also improves the accuracy of the data processing. In order to achieve the constant speed, this detecting system uses a high-resolution optical encoder to precisely control the motor, so as to ensure the stability during the rod movement processing. By the above two breakthroughs in the key technologies, this detecting system can eventually achieve a large number of good performances such as given time, concentration values, given deformation and automatically return to the starting point and so on.

The entire detecting system is mainly composed of the upper control system unit and the lower node control unit, and the detail structure is shown in Figure 1.
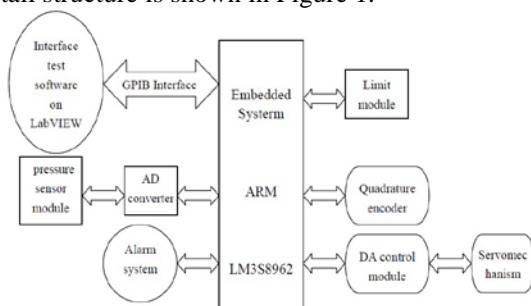

Figure1. The structure of the detecting system

3. HARDWARE DESIGN

Hardware platform is the basis of achieving the correct test of the FCCL and accurately trouble shooting ,whose design will directly affect the entire automated performance test of the system. The hardware platform of the detecting system includes the ARM master module, the GPIB interface module, the pressure signal acquisition and conditioning module, the DA control the motor module and the Man-machine interface test software of LabVIEW.

The choice of the ARM processor will directly affect the overall performance of the detecting system. In this detecting system, we choose TI's LM3S8962 microcontroller, which is usually designed for industrial applications including factory automation, motion control, test and measurement equipment. It integrates a wealth of on chip resources: containing 256 kB single-cycle Flash, 64kB single-cycle access of SRAM;

containing four General Purpose Timer Module (GPTM), each module offers two 16-bit timer / counter, or as containing a 32-bit timer module; 10/100 Ethernet controller; with a synchronous serial (SSI) interface and 3 fully programmable control 16C550 UART interface, support for IrDA operation, and containing an I2C module; 3 PWM signal modules, each module with a 16-bit counter, two comparators, two PWM signal generator, and a dead-band generator; interface with Quadrature Encoder (QEI); containing more general-purpose IO port, the most high tolerance for 5V[1-4].

In particular, in order to avoid the ARM controller being damaged in the course of the test, this detecting system will isolate the ARM and the periphery of AD sampling, motor drive and other control and communication module, i.e., one adopt a kind of multi-channel high-speed digital optical coupler ISO7240 to achieve the communication among the ARM and the GPIB, high-speed AD, DA.

3.1. GPIB Interface Module Design

GPIB interface card has been applied very widely, but in view of the complexity of the IEEE488 protocol, most equipment manufacturers are direct purchase of foreign production GPIB card, which is expensive and difficult to maintain. Therefore, the development of the IEEE488 interface board is imperative and will also have a large market in the country. To this end, one chooses the NI Company's TNT4882 GPIB interface chip and designs the following interface chip schematic.
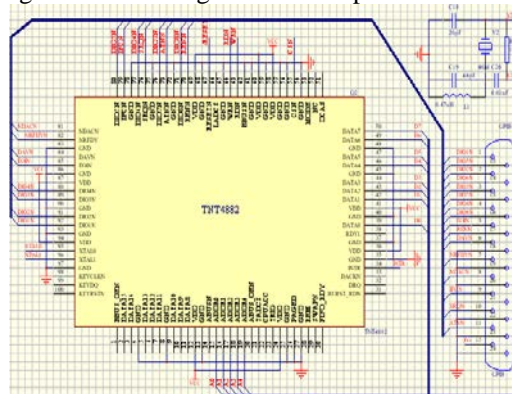

Figure2. TNT4882 interface chip circuit desig

In Figure 2, (DIO1N-DIO8N) used to transmit data and command information which is connected to PB port of ARM.

In order to save the IO port resources, one uses the 74HC573 latch to switch the address information and data information,

and use SN74LVC4245A to transform 5Vwith 3.3V level so as to ensure the normal communication between TNT4882 and ARM.

Bus interface functions includes: source shaking hands, speaking, listening, service requests, equipment to remove the trigger group, query, and the master control signal lines. We use those five signal (ATN, EOI, IFC, REN, SRQ) lines and system commands to accomplish these functions. But only the use of speaking, listening, inquiry, data transmission can be

effectively achieved. The three hand-shake lines (DAV NDAC, NRFD) are used to ensure that data is correct transmission [5].

In order to achieve the versatility of the object-oriented thinking-based GPIB interface, this paper uses a GPIB interface class as a GPIB interface card and the upper interface according to the GPIB dynamic link library. The main function is used to complete a variety of information transfer between the listeners and speakers. One communication interface class must have the following basic functionality:

(1) Completion of the initialization of the interface;
(2) Sending commands to the instrument through an interface class;
(3) Reading the instrument data returned from the instrument through the interface class;
(4) Closing the communication interface.
Therefore, one designs the following interface method: open the GPIB card communication interface, then get the handle of the instrument control; and then read string GPIB_ReadS-tring ()from the GPIB interface; after write to the GPIB interface the string GPIB_Write String (); and finally close the opened communication interface.

3.2. Pressure Sensor Conditioning Module Design

To design the following pressure sensor signal conditioning circuit as shown in Figure 3, where the specific design ideas are as follows: first, we lost the weak voltage signal of the pressure sensor output of the two roads and bridges to the design of pressure sensor signal conditioning circuits(the power signal and the voltage signal of strain pressure Figure 3, IP and OP), by two-way symmetrical LC low-pass filter circuit to filter out low frequency jitter caused by supplied voltage signal, and then after the Operational Amplifier filtered AD8222 and amplified by the dual-channel adjustable gain ADS1256 differential transmission to internally adjust the gain (1-128 times), low-noise high-resolution 24-bit AD converter chip (the chip data output rate of up to 30K samples / sec). ADS1256 chip programmed to control the sampling data improves the self-correction and system calibration, and then filtered by a programmable digital filter through SPI serial data port transferring data to ARM.
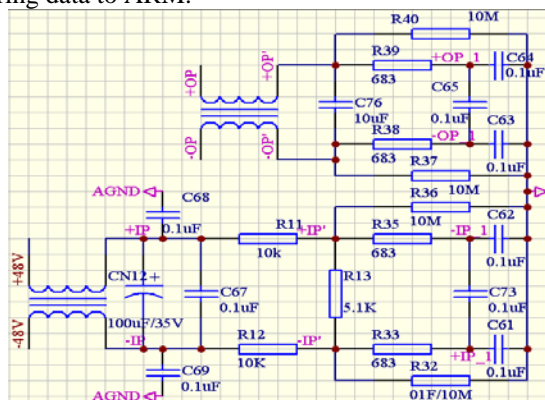

Figure3. Sensor signal conditioning circuit diagram

In order to reduce the ripple caused by jitter interference of

voltage ripple, the system has been designed with positive and negative 48V AC voltage to the bridge power supply to reduce the interference by increasing the supplied pressure differential. After the AD conversion, analog and digital filtering, data read by the ARM stable at the deviation of 2mV in the full scale of 5V. Then one can achieve high-precision pressure detection.

3.3. Motor Drive Module Design

In order to achieve precise control for motor speed, one uses 12 serial transmission of high-precision low-voltage DA chip DAC7512 to design the circuit. One use the 5V (ERROR_HI) voltage signal produced operational amplifier OP07 through the driver board to drive the motor.

The detection system introduces PID control algorithm to control the motor with who combine high performance DA and encoder etc to form an effective closed-loop to realize the motor speed control of constant speed, stability. PID parameter tuning process makes full use of the advantages of host computer LabVIEW, such as data logging, data and graphical display, numerical computation, data storage and so on and usesthe Ziegler-Nichol curve response to achieve the parameters of the controller self-tuning. The tuning process of parameters requires the calculation of performance indicators in the current system, such as overshoot and adjustment time. The calculation of performance indicators need long-term collection and analysis some output data of embedded platform, then read data, storage, graphics, analysis of operations. Variable kp, ki, kd generated by LabVIEW, in which ki = kd = 0, kp is a non-zero value, at the beginning kp is relatively small; LabVIEW puts kp, ki, kd into the control box as a control box to control the parameters of the algorithm through the GPIB port. Continuously increasing the value of kp until the oscillation phenomenon occurs. Now the controller output value of the oscillation to a constant value, then one writes down the limit gain ku and the period of oscillation Tu. If it does not oscillations one can appropriate to increase the kp value, on this basis to re-generate the value of kp, ki, kd which are sent to the lower machine to start a new test. The entire tuning process by LabVIEW record data, analyze data to determine adjustments. kp = 0.6ku, ki = 2kp \ Tu, kd = 0.125kp ,kp = 0.24, ki = 0.0024, kd = 6 are the tuning parameters of PID.

4. SYSTEM SOFTWARE DESIGN

Part of a software module based on the the LM3S8962 architecture system includes tasking embedded systems, PC LabVIEW interface for monitoring and data processing procedures, data acquisition communication procedures etc.

4.1. Tasking Embedded Systems

IAR PowerPac RTOS is a real-time operating system based on the priority control, which has a high level of optimization capabilities to occupy a very small space on the RAM and

ROM, according to the need for optimization of speed and functionality. Its core has a comprehensive process scheduling modules, file management module and power module [6]. The IAR EMARM integrated LM3S8962 the development environment and rich in API function to help to short the development cycle. In order to improve the system co-processing capabilities of real-time multi-tasking system, the design achieves PowerPac RTOS transplantation on the LM3S8962. One uses the priority tasks of multi-tasking algorithm to ensure the special requirements of the response time of motor and AD sampling. This will not only avoid the single-task system due to an infinite loop and the transmission delay and wasted time, but also can improve the resolution of the system. One of the key technologies of an RTOS is designed the control system logical structure, Figure 4 shows the logical structure of the detection system:
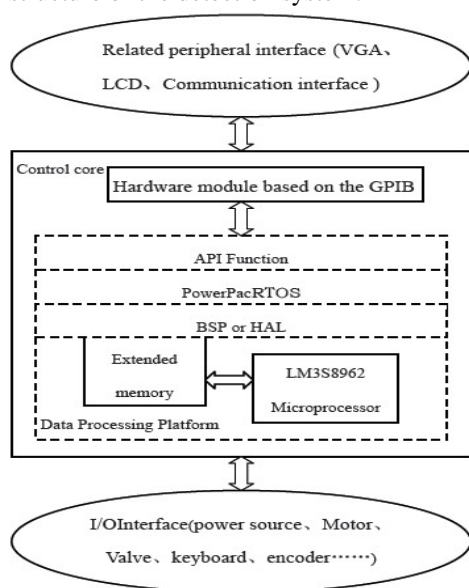

Figure4. Control system logic chart

The system is mainly to complete the choice of the velocity (5.08mm / s, 50.8mm / s), acquisition of the pulling data, displacement and tension state real-time display and operation control. Therefore, the system needs to create a total of four tasks: (1) the choice of the velocity; (2) collection of the pulling data; (3) real-time display of the displacement and tension states; (4) driving control of the motor. The priority of tasks is ordered decreasing and the information between tasks is transmitted by E-mail. Perform the task (1) when the initialization of system is completed; then drive motor task (4) in accordance with the parameters set by movement, the LM368962 microprocessor driven pressure sensor and optical encoder, real-time data acquisition, these data has been processed by the microprocessor, to determine whether the motor speed deviation from the set value; the deviation Δi is greater than or equal to allow deviation from the error δ (to avoid the motor movement jitter), task (3) into the ready state; high priority of the task (3) seize the right to the use of the CPU to complete the correction processing and parameter status

display; through the transfer of the semaphore, the task (2) to enter the ready state, completed multiple acquisitions of the AD, the motor speed processing of data; along with task (3) process the data and determine whether the results passed to the task (3) correction and status display; otherwise, the task (4) to enter the running state, the stable rotation of the drive motor.

4.2. Host Software Design

The basic programming unit of LabVIEW graphical programming language is a virtual instrument (VI). VI (and sub-VI) includes the three main parts: the front panel, block diagram, and icon / connector. In the application of this project through the GPIB interface controlling the ARM, one need design the application based on LabVIEW. The design of monitoring and control system software uses a sequential branching structure, so the application software is divided into three categories: processing each layer interface sub-VI; signal acquisition and processing sub-VI; sub-VI communication with GPIB devices.

4.2.1 Data Display

Those data show that the observational collected data are used for visually display. LabVIEW graphical user interface displays the data obtained by the host computer via GPIB interface into communication, which is not much difficulty. In contrast, if C or VC software directly used regardless of upper or lower machine programming is a relatively trouble, at the same time VC software compatibility upgrades are not good as LabVIEW [7]. This is precisely the advantage of LabVIEW embedded development. The specific methods: through VISA Read reading the string buffer, then scanning the string, the conversion in accordance with the format string (% f), and then converted characters are sent to test the interface displacement and tension in real time to show the icon of the box with the waveform chart (shows the power change waveform) data for the front panel graphic display. Figure 5 is the tensile strength testing interface.

4.2.2 Data Analysis Functions

In order to improve the accuracy of pressure and displacement, the system is programmed by software in real time, directly to the test data analysis and processing. ARM for the numerical analysis, data storage, high-capacity data recording requirements [8] appeared to be inadequate, especially for floating-point operations accumulated error is relatively large. However, LabVIEW has the great advantage for data logging, data, graphical display, numerical computation, data storage, so this detection system using LabVIEW as the data analysis tools greatly enhances the system power operation, PID parameter tuning, tension stability treatment and pressure precision handling performance.

Figure 5 (a) is a graphical display of the field test results, the pull of the vertical axis of each cell represents the size of

the units kgf, horizontal rod movement distance in mm. Power is an important indicator to reflect the test performance, power $\int_{t1}^{t2} F(t)S(t)dt \over t2-t1$, where t1 is the value set by the system, t2 is the system automatically recognizes the value. F is the tension and S is the displacement, which are both a function of time t. Figure 5 (a) the power P solving an integral block diagram of the LabVIEW can achieve accurate power calculation.
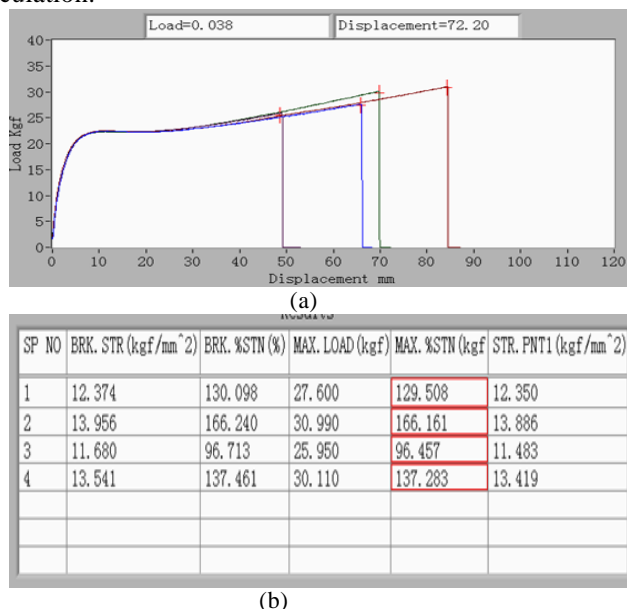

(a)

(b)

Figure5. Tensile strength properties of the test results

The smoothness of the curves in Figure 5 (a) reflects the degree of precision of the final results and the pros and cons of the material properties. This system is designed by self-tuning PID algorithm to process the motor speed, which guarantees the smooth of the displacement. In addition, the pulling force data, filtered by hardware and software, is processed by library functions of LabVIEW. It therefore ensures the constancy of pulling force. Based on the above data processing, the waveform of curves in Figure 5(a) can become more smoothly. Moreover, the test results can be accurate to the um level (See Figure 5(b)) , which significantly increases the measurement accuracy comparing with the original mm level.

5. CONCLUSIONS

(1) This paper takes full advantages of the collaborative ability of the multitasking real-time embedded systems to ensure a rapid data processing and timely communications requirements, and simultaneously reduce the size and power consumption of the controller to improve performance and decrease the cost. The designed system can achieve a good operating system transplant, which is conducive to the promotion of the system.

(2) PC control software, developed by using LabVIEW's powerful graphical user interface (GUI), can be convenient to achieve the design of control systems and human-machine interface. LabVIEW virtual instrument to instrument control is concentrated in the software module that can be used a variety of ways to display the data collected. The results of the analysis and control process will be more conducive to the development of new products.

This system has been put into production since 2011. The actual operation of the FCCL detecting system shows that it has the good performances in resolution, response speed and stability. This detecting system not only improves the level of automated inspection, but also improves the test accuracy. In addition, it is easy to upgrade and the corresponding upgrade cost is very cheap, which is worth promoting in the associated industry.

6. ACKNOWLEDGEMENTS

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